Chain Systems of Harmonic Quantum Oscillators as a Fractal Model of Matter and Global Scaling in Biophysics

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In this paper we introduce chain systems of harmonic quantum oscillators as a fractal model of matter and apply it to the analysis of frequency ranges of cyclical biological processes. The heuristic significance of global scaling in biophysics and medicine is discussed.

Introduction

Normal matter is formed by nucleons and electrons because they are exceptionally stable. Their lifespan tops everything that is measurable, exceeding 10^{29} years for the proton and 10^{28} years for the electron [1]. The proton-to-electron mass ratio is approximately 1836, so that the mass contribution of the proton to normal matter is very high, for example in the hydrogen atom (protium) it is $1 - 1/1836 \approx 99.95$ percent. Consequently, the mass contribution of the electron is only 0.05 percent. In heavier atoms which contain neutrons, the electron contribution to atomic mass is even smaller.

In addition, protons and neutrons have similar rest masses (the difference being only 0.14 percent) which allows us to interpret the proton and the neutron as similar quantum oscillators with regard to their rest masses. the framework of the standard particle model [2], protons and neutrons are baryons, with the proton connecting to a lower quantum energy level and a much more stable state than the neutron.

Therefore, in [3] we have introduced a fractal model of matter as a chain system of oscillating protons. In [4] we have shown that scale invariance is a fundamental property of this model. As a consequence of this scale invariance, chain systems of oscillating electrons produce similar series of eigenstates so that the proton model mass can be derived from the electron rest mass and vice versa. Furthermore, the interpretation of the Planck mass as an eigenstate in a chain system of oscillating protons has allowed us to derive the proton rest mass from fundamental physical constants [5].

Scale-invariant models of natural oscillations in chain systems of protons also provide a good description of the mass distribution of large celestial bodies in the Solar System [6]. Physical properties of celestial bodies such as mass, size, rotation and orbital period can be understood as macroscopic quantized eigenstates in chain systems of oscillating protons and electrons [7]. This understanding can be applied to an evolutionary trend prognosis of the Solar System but may be of cosmological significance as well. In [8] we have calculated the model masses of unknown planets in the Solar System.

In this paper we apply our fractal model of matter as a chain system of oscillating protons and our hypothesis of global scaling [7] to the domain of biophysics, especially to the analysis of frequency ranges of cyclical biological processes.

Methods

In [4] we have shown that the set of natural frequencies of a chain system of harmonic oscillators coincides with a set of finite continued fractions $\mathcal{F}$, which are natural logarithms:

$$\ln(\omega_{jk}/\omega_{00}) = n_{j0} + \cfrac{z}{n_{j1} + \cfrac{z}{n_{j2} + \ddots + \cfrac{z}{n_{jk}}}} = \qquad (1)$$

$$= [z, n_{j0}; n_{j1}, n_{j2}, \ldots, n_{jk}] = \mathcal{F},$$

where ω_{jk} is the set of angular frequencies and ω_{00} is the fundamental frequency of the set. The denominators are integer: $n_{j0}, n_{j1}, n_{j2}, \ldots, n_{jk} \in \mathbb{Z}$, the cardinality $j \in \mathbb{N}$ of the set and the number $k \in \mathbb{N}$ of layers are finite. In the canonical form, the numerator z is equal 1.

Any finite continued fraction represents a rational number [9]. Therefore, all frequencies ω_{jk} in (1) are irrational, because for rational exponents the natural exponential function is transcendental [10]. This circumstance presumably provides for the high stability of the oscillating chain system because it avoids resonance interaction between the elements of the system [11].

In the case of harmonic quantum oscillators, the continued fraction (1) defines not only a fractal set of natural angular frequencies ω_{jk} and oscillation periods $\tau_{jk} = 1/\omega_{jk}$ of the chain system, but also fractal sets of natural energies $E_{jk} = \hbar \cdot \omega_{jk}$ and masses $m_{jk} = E_{jk}/c^2$ which correspond with the eigenstates of the system. For this reason, we have called the continued fraction (1) the "fundamental fractal" of eigenstates in chain systems of harmonic quantum oscillators [4].

We hypothesize the scale invariance based on the fundamental fractal $\mathcal{F}$ (1) , calibrated by the properties of the proton and electron, is a universal characteristic of matter. This hypothesis we have called 'global scaling' [7].

In order to test global scaling on frequencies of cyclical biological processes we must calculate the natural logarithm of the process-to-proton frequency ratio. The proton angular frequency is $\omega_p = m_p c^2/\hbar = 1.425486 \cdot 10^{24}$ Hz,

Table 1: Frequency ranges of some cyclical biological processes and the corresponding attractor nodes of the fundamental fractal $\mathcal{F}$ (1), with the proton frequency $\omega_p = 1.425486 \cdot 10^{24}$ Hz as fundamental.

cyclic process of human physiology	**frequency range ω, Hz**	**ln (ω/ω_p)**	$\mathcal{F}$
adult relaxed breathing [13]	0.22..0.27	−57.13.. − 56.94	$[-57; \infty]$
adult relaxed heart rate [14]	0.83..1.5	−55.80.. − 55.21	$[-55; -2]$
brain activity delta	0.15..3	−57.52.. − 54.52	$[-57; -2]..[-54; -2]$
brain activity theta [12]	3..8	−54.52.. − 53.53	$[-54; -2]..[-54; 2]$
brain activity alpha	8..13	−53.53.. − 53.06	$[-53; -2]..[-53; \infty]$
brain activity beta	14..34	−52.97.. − 52.06	$[-53; \infty]..[-52; \infty]$
brain activity gamma	35..250	−52.05.. − 50.10	$[-52; \infty]..[-50; \infty]$
muscle vibration [15]	22..24	−52.53.. − 52.44	$[-52; -2]$
flicker fusion threshold [16]	60..120	−51.52.. − 50.83	$[-51; -2]..[-51; \infty]$
newborn baby cry [17]	400..500	−49.62.. − 49.41	$[-49; -2]$
threshold of hearing [18, 19]	1900..2100	−40.55.. − 40.45	$[-40; -2]$

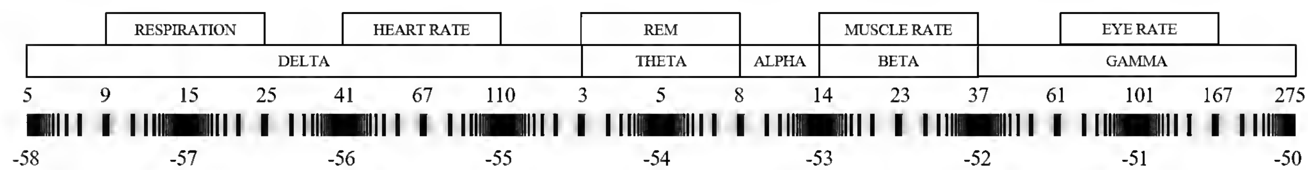

Fig. 1: Distribution (logarithmic representation) of frequency ranges (positive numbers) of human brain wave activity and other cyclical biological processes in the canonical projection of the fundamental fractal $\mathcal{F}$ (1) with the proton angular frequency $\omega_p = 1.42548624 \cdot 10^{24}$ Hz as fundamental. Negative numbers are logarithms and denote attractor nodes. Data taken from table 1.

where $m_p = 1.672621 \cdot 10^{-27}$ kg [1] is the proton rest mass, $\hbar$ is the Planck constant, c is the speed of light in vacuum. In the canonical form ($z = 1$), nodes of the fundamental fractal $\mathcal{F}$ (1) concur with integer and half logarithms.

For example, the frequency range of the theta electrical brain activity (theta waves, oscillatory pattern in electroencephalographic signals) is between 3 and 8 Hz [12] and the natural logarithm of the theta-to-proton frequency ratio is between $[-54; -2]$ and $[-54; 2]$ approximating the main node $[54; \infty]$ of the proton calibrated fundamental fractal $\mathcal{F}$ (1):

$$\ln\left(\frac{\omega_{\max theta}}{\omega_{\text{proton}}}\right) = \ln\left(\frac{8\,\text{Hz}}{1.425486 \cdot 10^{24}\,\text{Hz}}\right) = -53.53,$$

$$\ln\left(\frac{\omega_{\min theta}}{\omega_{\text{proton}}}\right) = \ln\left(\frac{3\,\text{Hz}}{1.425486 \cdot 10^{24}\,\text{Hz}}\right) = -54.52.$$

Results

Table 1 shows the logarithms of frequency ranges of some cyclical biological processes and the corresponding attractor nodes (integer and half logarithms) of the fundamental fractal $\mathcal{F}$ (1).

Figure 1 shows the distribution (in logarithmic representation) of frequency ranges of brain wave activity and other cyclical processes of human physiology in the fundamental fractal $\mathcal{F}$ (1) with the proton angular frequency $\omega_p = 1.42548624 \cdot 10^{24}$ Hz as fundamental. Negative numbers are logarithms and denote attractor nodes. Positive numbers are frequencies, given in cycles per minute within the delta-range, and given in Hz within the theta, alpha, beta and gamma ranges.

Although the analyzed processes are of very high complexity, figure 1 shows that the frequency ranges of electrical brain activity (oscillatory patterns in electroencephalographic signals) and of other cyclical biological processes correspond with attractor nodes of the fundamental fractal $\mathcal{F}$ (1). This fact supports our hypothesis of global scaling.

Conclusion

Frequency ranges of electrical brain activity and of some other cyclical biological processes coincide well with the proton calibrated fundamental fractal $\mathcal{F}$ (1) which would indicate that these cycles may have a subatomic origin. It should also be considered that the frequency ranges of electrical brain activity are common to most mammalian species [20, 21].

The accordance of the brain wave frequency ranges with the proton calibrated fundamental fractal $\mathcal{F}$ (1) not only sup-

ports our hypothesis of global scaling, but also suggests an understanding of the biological organism as an oscillating chain system. This view could be of medical significance as well.

Scale invariance as a property of biological processes is well studied [22, 23] and it is not an exclusive characteristic of adult physiology. For example, the heart rate and the respiratory cycle of the fetus are related in the same way as in the adult [24]. Perhaps even the Weber-Fechner law – "intensity of sensation is proportional to the logarithm of stimulation" [25] – can be understood as a consequence of scale invariance in chain systems of cyclical biological processes.

Furthermore, global scaling suggests that the electrical brain activity continues beyond the known gamma range, because higher frequency processes like voice and hearing have to be brain-controlled as well. It is likely that traditional methods of electroencephalographic signal analysis are unable to separate high frequency patterns because of their very low amplitude. However, global scaling allows us to calculate the frequency ranges of such ultra-gamma activity (for which we propose the name "epsilon"). The frequency ranges of this very dynamic "epsilon" activity should be between $\omega_p \exp(-50) = 275$ Hz and $\omega_p \exp(-49) = 747$ Hz.

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